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Pre and Post Seismic Assessment for an Onshore Oil and Gas Facility in Sabah

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ABSTRACT

Pre and post seismic assessment of an onshore oil and gas facility in Sabah examines the integrity and vulnerability of the assets against earthquake events. Due to the design requirements at the time of project inception, seismic considerations were not included. The necessity for this assessment arises from the heightened seismic activities in Sabah and nearby regions. Pre-seismic assessment evaluates the integrity of existing structures against seismic effects. This involves soil liquefaction susceptibility assessment and seismic reassessment of selected structures and equipment foundations. Post-seismic assessment identifies defects and seismic vulnerabilities in assets common to oil and gas facilities in accordance with established methodologies. For the pre-seismic assessment, one structure was found with a minor integrity concern, which calls for a more detailed analysis to determine the suitable solution, such as strengthening. As for the post-seismic assessment, some vulnerabilities were identified, and simple measures are recommended to eliminate these, such as providing more restraints to certain equipment. The outcomes of both assessments contribute to enhancing the seismic resilience of the facility, thereby mitigating potential risks from future seismic events while establishing best practices for this industry.

Keywords: *Seismic evaluation; structural integrity; seismic vulnerabilities; onshore oil and gas*

1. Introduction

The 2015 Sabah earthquake struck Ranau, Sabah, with a moment magnitude of 6.0 on 5th June 2015 which lasted for 30 seconds. The earthquake was the strongest to affect Malaysia since 1976. Tremors were also felt in Tambunan, Tuaran, Kota Kinabalu, Inanam, Kota Belud, Kota Marudu, Kudat, Likas, Penampang, Putatan, Kinarut, Papar, Beaufort, Keningau, Beluran, Sandakan, Kunak, Tawau in Sabah and as far afield as Federal Territory of Labuan, Lawas, Limbang and Miri in Sarawak as well as Bandar Seri Begawan in Brunei. There are several onshore oil and gas facilities in Sabah for example in Tuaran, Kimanis etc. Location of the earthquake epicentres and the effect to surrounding area is shown in Figure 1.

Pre and post seismic assessment for civil and structural assets of oil and gas facilities in Sabah is carried out considering the recent cases of seismic activities especially in Sabah and nearby regions of Indonesia and the Philippines, there is a high possibility that the current trend of earthquakes will impact the civil and structural assets. This paper describes the pre and post seismic assessment

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methodology, the results and findings and the way forward recommendations from the findings. The scope of the study including the screening for assets selection for detail seismic re-assessments, visual inspection defects mainly to civil and structural assets and seismic vulnerabilities which are common to oil and gas facilities.

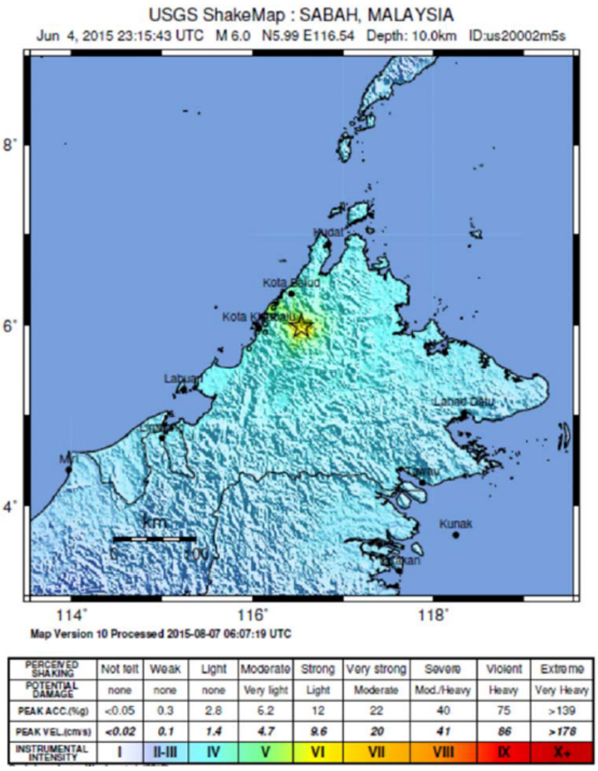

Fig. 1. Sabah Jun 5th 2015 earthquake epicenter and the effect to surrounding area

2. Methodology

Methodology for pre seismic assessment of comprises of:

i. Screening for assets selection for detail seismic re-assessment
ii. Structural analysis incorporating seismic loading using modal response spectra analysis method and structural capacity checking
iii. Soil liquefaction susceptibility assessment

Methodology for pre seismic assessment of comprises of:

i. Visual inspection for identification of defects for post seismic events is mainly in accordance with publication by Consortium of Universities for Research in Earthquake Engineering (CUREE).
ii. Identification of seismic vulnerabilities for elements as mainly referencing to Guidelines for Seismic Evaluation and Design of Petrochemical Facilities by ASCE.
iii. Interviews with facility personnel to gather any relevant information during and after the earthquake event.

2.1 Screening for Assets Selection for Detail Seismic Re-Assessment

Assets screening for detail seismic re-assessment is based on the following guideline steps shown in Figure 2:

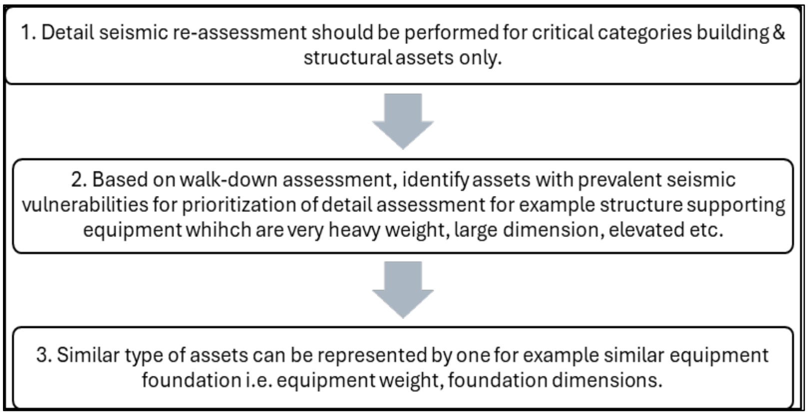

Fig. 2. Seismic re-assessment screening

The assessment results of these major assets would give a good indication of the overall the facilities performance against seismic affect. For this case study, four (4) major assets which are under critical assets category are selected for detail seismic re-assessment which are:

i. Control Building
ii. Pipe rack
iii. High pressure flare stack
iv. Knock-out drum vessel foundations

2.2 Structural Analysis Incorporating Seismic Loading Using Modal Response Spectra Analysis Method and Structural Capacity Checking

Based on the seismic hazard zonation map (which are available during this study period) the predicted peak ground acceleration (PGA) values for this specific location in Sabah is 0.04 g for 475 years return period. This value will be the basis for seismic reassessment for structural analysis.

Modal response spectra analysis method is used for the application of seismic loading for all of the selected structures. The response spectrum model used in this analysis uses BS EN 1998-1 provided response spectra. Response spectra analysis in brief is an elastic dynamic analysis of a structure utilizing the peak dynamic response of all modes having a significant contribution to total structural response. Peak modal responses are calculated using the ordinates of the appropriate response. The structures were modelled and analysed using structural design software i.e. Staad Pro and the results were checked to determine the integrity against seismic loading.

2.3 Soil Liquefaction Susceptibility Assessment

Soil liquefaction is a condition where soil losses its bearing strength which can lead to failure of existing structures. Earthquake shaking and energy increase the pore water pressure within soils, which in turn, reduce the effective soil stresses and bearing capacity. This temporary reduction in soil bearing capacity can result in foundation failure. Soil liquefaction tends to occur in saturated loose sandy or silty soils. Factors affecting liquefaction potential include ground shaking intensity, earthquake magnitude or strong shaking duration and soil properties.

For the guidelines of soil liquefaction susceptibly assessment the documents [4] and [5] are used as the main technical references.

2.4 Visual Inspection for Identification of Defects and Potential Seismic Vulnerabilities in Plant Facilities

Visual inspection for identification defects for post seismic event was conducted in accordance with post-earthquake damage inspection checklist. This checklist is mainly based on publication by Consortium of Universities for Research in Earthquake Engineering *et al.,* [1] especially on the building elements

Identification for seismic vulnerabilities in plant facilities is based on Guidelines for Seismic Evaluation and Design of Petrochemical Facilities by ASCE [2]. Seismic vulnerabilities in this assessment are defined as inherent properties, features or detailing that are more prone to damage in occurrence of a seismic event. The following are some common examples in plant facilities where this situation exists:

1. Modification of load path on structure which will result in the structure to behave not as per intended under certain loading conditions.
2. Inadequate anchorage which could reduce the tension capacity of an anchor bolt such as:

    - Missing bolt & nuts
    - Inadequate edge distance (typically not less than 50 mm)
    - Damage to the concrete embedment

3. Electrical equipment vulnerabilities such as:

    - Electrical equipment which are not anchored
    - Cabinets that are not bolted together may pound against each other
    - The batteries themselves should be restrained from falling off the rack.
    - The battery rack should be structurally sound, capable of resisting transverse and longitudinal loads

4. Instrument equipment vulnerabilities:

    - Instrument equipment which are not anchored

5. Chemical Storage Areas vulnerabilities:

    - Cabinets are not secured to prevent falling.
    - No restraints to prevent contents from being spilled from shelves

6. Gas Cylinders vulnerabilities:

    - Not adequate supports on both the upper and lower portion of the cylinder to prevent the cylinders from falling and sliding or rolling.

7. Piping vulnerabilities such as:

   - situations where the pipeline is near the edge of the support and could slide off
   - inadequate piping flexibility to withstand differential motion between two anchor (fix) points

8. Storage tanks vulnerabilities due to poor detailing

3. Results
3.1 Findings

Findings of the pre and post onshore seismic assessment are described as follows.

3.1.1 Structural analysis and structural capacity checking against seismic loading

Findings from the structural assessment results are as follows:

i. Control building structure – it was found that some of the structural members have inadequate strength against seismic effects.
ii. Piperack structure – all members have adequate strength against seismic effects
iii. High Pressure flare stack - all members have adequate strength against seismic effects.
iv. Equipment foundations – all foundations have adequate factors of safety for stability and all holding down bolts have adequate strength against seismic effects.

From the assessment findings, integrity concern against seismic effects is only on the Control Building structure. For all other structures that were selected for the seismic re-assessment the results shows that these assets are having design reserve strength which are adequate against seismic effect. As such there are no immediate integrity concern regarding these assets.

As way forward recommendation, the owner of assets to undertake a next phase of study for Control Building which should involve an extensive analysis of the overall or majority of the structural members of this building. From the result of the detail study is then can be determined whether strengthening is feasible or other method or approach need to be adopted such as to performed static push over analysis.

3.1.2 Soil liquefaction assessment

There are existing boreholes that are available for this particular site from the findings, all boreholes show that, approximately the top 20 m of soil layer (from ground level) consists of sands layer which is cohesionless soil.

Based on PTS 11.10.02 [3], the soil characteristic described above will be susceptible to soil liquefaction condition in the event of an earthquake. However, the magnitude of earthquake that would cause the occurrence of liquefaction is not given in this PTS 11.10.02 [3]. Reference is then made to BS EN 1998-5 [4].

Based on this code [4], liquefaction hazard may be neglected if the site and soil fulfill the following conditions:

i. $\alpha. S < 1.5$

ii. the sands have a clay content greater than 20% with plasticity index PI > 10
with;
α = PGA of site on type A (rock) soil – for this site is 0.04 g for 475 years return period.
S = soil factor as per BS EN 1998-1 (in this case is taken as 1.5)
Hence for this site, $\alpha.S = 0.09 < 1.5$

Soil investigation report shows that the topsoil layer is having clay content of minimum of 21 % and plasticity index PI of minimum of 21. As such based on the guideline given in BS EN 1998 [5], this facility should not be at risk of liquefaction condition considering the magnitude of earthquake and site soil characteristics.

3.1.3 Defects due to seismic event (post seismic event)

From interviews and visual inspection carried out, the following are the summary of the findings with regards to common types of defects/damages following a seismic event:

From interviews with personnel in the oil and gas facility operation there is no alarm being triggered (e.g. potential gas leak, loss of containment, short circuit etc.) during the earthquake event.

i. No displacement of piping from its support locations
ii. No damage to anchor bolts of equipment's (such as pull out of concrete, crack at concrete embedment, stretching of bolts, missing or loosening of nuts etc. -attention is given to heavy and elevated equipment).
iii. No damage to anchor bolts and steel structure columns (e.g., pipe racks, pipe support, access platform, open shed etc.).
iv. No damage to steel structure bolted and welded connections.
v. No leaning or movement of pedestal and block support (foundation) for equipment.
vi. No distorted steel structure framings and damage to structural members (i.e. deflection and buckling).
vii. No buckling of tank shells and no lateral movement of tank shell from the pad.
viii. No damage to tank bund walls.
ix. No structural cracks on reinforced concrete building structural framing i.e. concrete beam & columns.
x. No damage to architectural finishes e.g. brick wall, glass window, flooring tiles, ceiling panels, lightings and HVAC fixtures.

3.1.4 Potential seismic vulnerabilities

During the visual inspection, potential seismic vulnerabilities were also being observed and the findings are as the following:

1. Stacked up container barrels with potential of tipping or falling shown in Figure 3.

Fig. 3. Stacked up container barrels

Best practice would be:

A. Containers more than 600 mm in height may not be stacked more than two high without supplemental support to prevent the tipping or falling of the containers during an earthquake.While it is preferable not to stack containers, if containers are stacked, every container must sit directly on a pallet, with palletized containers not stacked more than two high (as shown in Figure 4).

Fig. 4. Preferable stack containers

2. Electrical equipment

i. Uncertainty on the availability of anchorage of the electrical cabinets to the floor Refer to Figure 5
ii. Cabinets not attached/tied together which may pound on each other (not so critical if the cabinets are anchored to floor). Refer to Figure 6.
iii. Batteries are not secured onto the racks. Refer to Figure 7(a) and Figure 7(b) for example of a secured method.

Fig. 5. Anchorage is unknown

Fig. 6 Cabinets not attached/tied together which may pound on each other

(a) (b)

Fig. 7. (a) Batteries are not secured onto the racks (b) example of secured batteries rack

4. Conclusions

Pre seismic assessment for civil and structural assets at an onshore oil and gas facility in Sabah is conducted in the objective of assessing the integrity of the assets against seismic effects considering the recent and frequent earthquake occurrence especially in Sabah. This is particularly important since the original design of the terminal did not consider seismic loadings or seismic design provision. From the findings majority of the asset structures are having adequate design reserve strength against seismic effect.

As for post seismic assessment, based on inspection findings this facility in Sabah is not being affected by the previous Sabah earthquake and the effects can be considered as negligible. However, there are some seismic vulnerabilities identified which will be a good practice if those could be addressed such as:

i. Ensure all chemical storage containers are secured with proper and appropriate methods.
ii. Improve the flexibility of any identified rigid piping
iii. Ensure anchorage of electrical cabinets
iv. Secure batteries with proper racking

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